

VARIABLE SPEED COMPRESSOR COOLING SYSTEM

BACKGROUND

[0001] The present invention relates to compressors. More particularly, the present invention relates to cooling systems for compressors.

[0002] There are two principle designs of compressors, contact cooled and oil free. Contact cooled compressors are generally defined as compressors that inject coolant into the compression chamber to lubricate, remove the heat of compression, and seal the clearances between the compressor rotors. Oil free compressors are generally defined as compressors that separate the air and oil systems, if required, to prevent contamination of the compressed air. In both cases, the air and oil or coolant must be cooled to remove the heat of compression and heat from friction.

[0003] Air-cooled air compressors remove the heat from the air and oil by using fans or blowers to force or draw air through a heat exchanger or combination of heat exchangers. Typically, air-cooled cooling systems are sized by matching the fan or blower with a heat exchanger to meet the Limiting Ambient Temperature (LAT) and Cold Air Temperature Difference (CTD) requirements for the compressor. The LAT is defined as the maximum ambient temperature the compressor will operate. The CTD is defined as the difference between the compressed air discharge temperature and the ambient air temperature. The LAT and CTD requirements are fixed values based on predicted values. The predicted values are typically chosen to correspond to worst case scenarios. In most applications, the compressor does not operate in the worst case conditions.

[0004] Current cooling systems incorporate one of two methods of controlling fans or blowers: (1) fixed speed operation and (2) variable speed operation. In the fixed speed designs, the speed of the fan or blower remains constant regardless of the operation of the compressor or the ambient conditions or customer's requirements. In the current variable speed applications, a single variable frequency drive (VFD) is used to control the speed of the compressor and fan or blower. This method of variable speed control requires the speed of the fan or blower to be adjusted linearly with the speed of the compressor.

[0005] Neither of the two current fan and blower control methods provides the customer an optimized cooling system for any given application.

SUMMARY

[0006] The present invention relates to a compressor assembly. The compressor assembly includes one or more compressors associated with compressor drive means. The compressor drive means may include constant speed drives or variable speed drives. A cooling system is positioned downstream from the compressor and includes at least one air circulator, for example, a fan or a blower, and at least one heat exchanger. The air circulator is associated with a variable speed circulator drive means, for example, a variable speed motor, the speed of which can be adjusted independent of the compressor drive means. One or more sensors are associated with the circulator drive means. The sensors sense desired variables, for example, ambient temperature, air end discharge temperature, coolant injection temperature, package discharge temperature, compressor drive means speed, dryer inlet temperature, compressor point of use temperature or air end discharge pressure. The speed of the circulator drive means is adjustable in response to real-time sensed conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 is a schematic flow diagram of a compressor assembly according to a first embodiment of the present invention.

[0008] Fig. 2 is a schematic flow diagram of a compressor assembly according to a second embodiment of the present invention.

[0009] Fig. 3 is a schematic flow diagram of a compressor assembly according to a third embodiment of the present invention.

[0010] Fig. 4 is a schematic flow diagram of a compressor assembly according to a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] The present invention will be described with reference to the accompanying drawing figures wherein like numbers represent like elements throughout. Certain terminology, for example, “top”, “bottom”, “right”, “left”, “front”, “frontward”, “forward”, “back”, “rear” and “rearward”, is used in the following description for relative descriptive clarity only and is not intended to be limiting.

[0012] Referring to Fig. 1, a compressor assembly 10 that is a first embodiment of the present invention is shown. The compressor assembly 10 provides compressed fluid, preferably air, to downstream components via an outlet 28. The downstream components (not shown) may be any of various devices, for example, further conditioning components like dryers, filters and the like, intermediate storage tanks, or end user tools, motors or the like.

[0013] The compressor assembly 10 generally comprises a compressor 2 having an air inlet 4 and an air outlet 6. The compressor 2 can have various configurations, for example, it may be a conventional single-stage reciprocating compressor, a dual-stage reciprocating compressor, a rotary screw compressor, a centrifugal compressor, or a scroll compressor among others. The compressor 2 may be contact cooled or oil free.

[0014] The compressor 2 is driven by a compressor drive 3. The compressor drive 3 may be a conventional electric motor or a combustion engine amongst others. The compressor drive 3 may be constant speed drive or alternatively may be a variable speed drive ("VSD").

[0015] Air, or another intended fluid, enters the compressor 2 through the inlet 4 and is compressed to a desired pressure. The compressed fluid exits the compressor 2 through the fluid outlet 6 and travels to a downstream cooling system 8. The cooling system 8 generally comprises a heat exchanger 12 and an air circulator 14, for example a fan or a blower, for drawing or forcing air across the heat exchanger 12. The air circulator 14 is driven by a variable speed drive ("VSD") 16 associated therewith. The VSD 16 preferably comprises a variable speed frequency drive and an electric motor. The compressed fluid travels through the cooling system 8 and the cooled, compressed fluid travels to the downstream components via the outlet 28. In addition to cooling the compressed fluid, the cooling system 8 may be utilized to cool the cooling fluid circulating through the compressor 2. A fluid loop (see Fig. 4) for carrying the cooling fluid from the compressor 2 to the cooling system 8 may be provided.

[0016] To achieve a desired condition of the compressed fluid, the air circulator VSD 16 is associated with at least one sensor 18 or other measuring device. The sensor 18 may provide sensed information to controller 20, for example, a CPU, which in turn provides a control signal to the air circulator VSD 16. Alternatively, the sensor 18 may provide sensed information directly to the air circulator VSD 16, as indicated by line 26 in Fig. 1. The air circulator VSD 16 would vary its speed in direct response to the sensed information. Communication between the sensor 18, controller 20

and air circulator VSD 16 may be transmitted through hard wiring or through wireless technology, for example, RF transmission, or a combination thereof. In response to the sensed information, the air circulator VSD 16 speed may be varied electronically and/or mechanically.

[0017] In the compressor assembly 10 illustrated in Fig. 1, the sensor 18 is a temperature sensor that is positioned between the compressor outlet 6 and the cooling system 8. The sensor 18 senses the temperature of the compressed fluid exiting the compressor 2 and provides, preferably continuously, such information to the controller 20 or directly to the air circulator VSD 16. The sensor 18 for sensing temperature can be an RTD (Resistance Temperature Detector), thermocouple, thermistor or other electrical device capable of translating a temperature within a predefined range into a varying potential or current, or, a filled-system device containing mercury or other temperature sensitive fluid. The temperature element can be mounted using a thermowell (not shown) or nude within the compressor discharge piping 6. The sensor 18 continuously measures the discharge gas temperature. A temperature measurement signal corresponding to the discharge gas temperature is provided to the controller 20. The controller 20 can accept a current, voltage or filled-system process variable input.

[0018] As such, the speed of the air circulator 14 can be adjusted in response to the real-time information provided by the sensor 18. For example, if the temperature of the compressed fluid increases, the air circulator VSD 16 is sped up such that the air circulator 14 draws or forces more air across the heat exchanger 12 to effect greater cooling.

[0019] Referring to Fig. 2, a compressor assembly 60 that is a second embodiment of the present invention is shown. The compressor assembly 60 is substantially the same as in the previous embodiment and like components have like numerals. In this embodiment, the sensor 18 is provided at the downstream outlet 28. The sensor 18 measures the temperature of the compressed fluid as it exits the cooling system 18. The air circulator VSD 16 may be controlled in response to this single variable. However, in the present embodiment, a second sensor 30 is associated with the controller 20. The second sensor 30 senses the ambient air temperature. The controller 20 can compare the sensed temperature of the compressed fluid (sensor 18) with the sensed ambient temperature (sensor 30) to determine the CTD. The air circulator VSD 16 can then be controlled to maintain the CTD within a desired range.

[0020] Referring to Fig. 3, a compressor assembly 70 that is a third embodiment of the present invention is shown. The compressor assembly 70 is similar to the previous embodiments and the like components have like numerals. The compressor assembly 70 has a pair of compressors 2, 2' and a pair of cooling systems 8, 8'. Each compressor 2, 2' has its own compressor drive 3, 3', respectively. Alternatively, a single drive may be utilized to drive both compressors 2, 2'. Each cooling system 8, 8' is also shown with its own air circulator VSD 16, 16', respectively. While a single drive may be utilized with both cooling systems 8, 8', it is preferred that each cooling system 8, 8' be provided with its own VSD 16, 16'. The compressors 2, 2' are shown in parallel, but may be connected in series or in any other desired configuration. In the illustrated configuration, fluid travels from each inlet 4, 4'; through compressors 2, 2' to outlets 6, 6', respectively; through cooling systems 8, 8' and outlets 28, 28', respectively, to a common outlet 40 and through dryer 42 to outlet 48. Outlet 48 connects to desired downstream components. The dryer 42 may be a refrigeration type dryer or a desiccant type dryer amongst others.

[0021] A plurality of sensors 18, 36, 38, 44, 46, 50 and 52 are positioned along the system to read various conditions. In the illustrated embodiment, the sensors sense the following information: sensor 18 sensors the temperature of the compressed fluid discharged from cooling system 8; sensor 36 senses the temperature of the compressed fluid discharged from the cooling system 8'; sensor 38 senses the pressure of the compressed fluid traveling through the common outlet 40; sensor 44 senses the temperature of the compressed fluid at the dryer 42 inlet; sensor 46 senses the temperature of the dryer cold air well; sensor 50 senses the temperature of the compressed fluid discharged from the dryer 42; and sensor 52 senses the ambient temperature. The number, type and positioning of the sensors may be varied.

[0022] All of the sensed information is provided to controller 20. The controller 20 also receives feedback from each of the drives 3, 3', 16, 16', for example, drive speed. The controller 20 gathers the raw information and may also configure and compare the information. For example, the controller 20 may use the sensed outlet pressure (sensor 38) to determine the pressure dew point at that point of the system. The pressure dew point may be compared with the compressed fluid temperature from each compressor 2,2' (sensors 18, 36) and determine if any system adjustment is required. As another example, the controller may configure the readings of the various dryer sensors 44, 46, 50 and compare such information to the known ideal operating conditions of the

dryer 42. The controller 20 continuously monitors and configures the data from any desired combination of the sensors 18, 36, 38, 44, 46, 50 and 52 and adjusts the air circulator VSDs 16, 16' to optimize the operating conditions of the compressor assembly 70. For example, the cooling system 8 may be sped up while the cooling system 8' is slowed down to provide a desired compressed fluid temperature (sensor 44) entering the dryer 42.

[0023] Referring to Fig. 4, a compressor assembly 80 that is a fourth embodiment of the present invention is shown. The compressor assembly 80 is substantially the same as in the previous embodiments and like components have like numerals. In this embodiment, the compressor 2 is an oil flooded compressor. The sensor 18 is positioned at the discharge outlet 6 of the compressor 2, and is preferably configured to measure the temperature of the discharged air/oil mixture. The air/oil mixture passes to a separator tank 82 where the oil is separated from the compressed air. Fluid conduit 84 carries the compressed air to the cooling system 8 and a fluid conduit 86 carries the separated oil to the cooling system 8. The compressed air passes through the cooling system 8 and travels to the downstream components via the outlet 28. The separated oil passes through the cooling system 8 and is redirected through conduit 88 back to the compressor oil inlet 5. A valve 90 is preferably provided along the fluid conduit 88 and is in communication with the controller 20. The controller 20 is configured to control the valve 90, and thereby regulate the amount of oil injected into the compressor 2, based on the various sensed parameters. In the illustrated embodiment, the sensed parameter is the temperature of the air/oil mixture at the compressor outlet 6. As such, the controller can control the temperature of both the compressed air and of the separated oil by controlling the cooling system VSD 16. Additionally, the amount of oil injected in to the compressor 2 can also be controlled to assist in maintaining the discharge temperature of the air/oil mixture within a desired range.

[0024] The above described embodiments are illustrative only and are not intended to be limiting. Other variations of the present invention will fall within the scope of this invention. Other components and devices may be positioned in the compressor assembly circuits and the relative position of the illustrated components may be varied.

*

*

*